XV. ADOT ADVANCED VEHICLE RESEARCH PROGRAM: 1997–2003

In June 2003, Under Secretary Jeffrey Shane of the U.S. Department of Transportation addressed a national meeting of Intelligent Vehicle Initiative (IVI) partners in Washington D.C. Having just witnessed IVI-advanced safety system demonstrations, he said, "These are powerful, elegant technologies, and they have the potential to help us save thousands of lives." He further noted that, "Vehicle-only systems have already proven highly effective in a number of applications."

This long-term ATRC in-house research project was mandated by the ADOT Research Council and by senior management in late 1997 to explore advanced vehicle technologies for Arizona. The research soon became focused on snowplows, and for five winters, the project has evaluated both infrastructure-based and on-board driver-assistance concepts. The fundamental research goal has been to improve the safety of ADOT's snowplow operators and the public, and to increase the effectiveness of the state's snowplow fleet.

Arizona is geographically a large area, with a relatively small population. Several key Interstate highway corridors carry very large traffic volumes across the state, and the "land bridge" concept of coast-to-coast cargo delivery is a crucial aspect of the nation's economy. In winter, transport traffic may also be diverted southward from other route corridors, so severe storms in northern Arizona quickly cause extensive regional problems with congestion, delays, and crash losses.

PROJECT SUMMARY: ADVANCED SNOWPLOW RESEARCH

The 6,216-mile Arizona State Highway System includes 3,992 miles that are designated ADOT snowplow routes, and 1,395 miles of those routes have frequent storm visibility issues. Winter conditions in the higher elevations are generally severe, although during the life of this project, the winter snowfall average fell significantly below the 30-year historical figure. Recent mild winter seasons constrained comprehensive operational evaluations of this project's IV concepts.

Table 10. Flagstaff Winter Storm Summary: 1997-2003

Winter Season (October to May)	Storm Events*	Snowfall: Inches**	ATRC Project: Research Phase
1997-98	27	108"	*Pre-Planning Stage*
1998-99	13	72"	Caltrans
1999-2000	18	74"	Caltrans
2000-01	25	125"	Caltrans & 3M
2001-02	10	39"	Caltrans & 3M
2002-03	14	55"	Bendix & Eaton VORAD
*6-Year Seasonal Average:	18	79"	
Historical Avg of Storm Events (30 yrs)	22.5	107"	*(1973-2003)*
Historical Avg since 1898 (105 yrs)		84"	*(1898-present)*

*Storms Greater than One Inch of Snow at Flagstaff
**Seasonal total snowfall recorded at Pulliam Airport / WX Observation Station

Source: National Weather Service records

As noted earlier in this report, the winter storm records vary dramatically between calendar year snowfall totals and those for the October to May winter season. The 2001-02 winter season had only 39 inches of snow at Flagstaff from November to March, while the calendar year totals were 131 inches in 2001, followed by 30 inches in 2002. Appendix A lists the past 30 years of Flagstaff-area snowfall records, which provide an indication of the relative severity of the regional winters across northern and eastern Arizona.

It is noteworthy that the advanced-snowplow focus of this research project was developed during the 1997-98 winter, when the snow total for the season was a "nearly normal" 108 inches, but since 1998, the Arizona winters have seldom been described as "normal."

Traffic Accident History: Wintry Conditions

The winter-season snowfall statistics are most directly relevant to the annual operational testing of advanced snowplow technologies, but calendar year summaries are normally used to generate the long-term historical averages. ADOT's crash statistics are also based on calendar year totals, so the total annual snowfall, not the seasonal figure, is the relevant statistic used in Table 11 to correlate crash and fatality/injury records to winter weather across Arizona.

Table 11. Arizona "Snowy and Icy" Crash Records: Six Winters

Statewide Motor Vehicle Crash Histories By Calendar Year							
Life of Project: 1997 - 2002							
Statewide Crash Data	1997	1998	1999	2000	2001	2002	6 Years: Average
Total "Snowy & Icy" Crashes	1,768	1,855	647	1,292	2,073	1,243	1,480
Snowy & Icy: Fatal Crashes	7	12	5	8	14	12	10
Snowy & Icy: Injury Crashes	371	453	206	318	518	322	365
Snowy & Icy: PDO Crashes	1,390	1,390	436	966	1,541	909	1,105
Total "Snowy & Icy" Fatalities	7	14	5	14	14	14	11
Total "Snowy & Icy" Injured	581	763	322	567	818	539	598
(PDO is: Property Damage Only)							
Total Snow- Flagstaff- Cal.Year:	*113*	*123*	*56*	*101*	*131*	*30*	*92" Avg*
Days more than 1 inch of snow:	*17*	*26*	*9*	*24*	*27*	*8*	*18.5 Avg*

Source: "Motor Vehicle Crash Facts" Annual Reports (various), ADOT Traffic Records Section

Table 11 shows crash records for six calendar years of the research project (2003 crash records were not yet available for this report). The Flagstaff weather records for this period show that the average number of storm days was 18.5, with a 92-inch average snowfall. These figures reveal a significant short-term decrease in the severity of recent winters, compared with 30-year records (Appendix A) showing 22.5 storms per winter on average, and 107 inches of snowfall.

The table shows a relationship for six calendar years between Flagstaff snow records and the Arizona crash history figures. Assuming that Flagstaff's figures provide some measure of the severity of winters across the state, then the "total crashes" in "snowy and icy conditions" do appear to vary generally with the storm records, both for total snow accumulation and recorded days of snowfall.

Figure 31. Storm Cleanup: An Icy Highway In Northern Arizona

The winter crash records are not extensive enough to be statistically significant, but they do imply the economic, social, and personal costs of every crash on a wintry roadway. Every crash record involves personal trauma and loss, increases the demands on emergency services and snowplow crews, compounds the storm-caused congestion, and has real economic impacts.

ATRC does not have sufficient performance data on the new advanced snowplow technologies for this project to quantify any specific benefits to ADOT of installing these systems in its fleet. If these systems could reduce the toll of winter highway crashes, the benefits to the state and its citizens would be tremendous. At a cost of between $3,000 and $7,500, any ADOT snowplow can be equipped with an advanced on-board warning system. In comparison, the National Safety Council estimates the economic loss from a single non-injury vehicle crash to be $6,200.

1997-2003 PROGRAM RESULTS: ADVANCED VEHICLE SYSTEMS

The key result of five winters of ADOT's snowplow evaluation project is the confirmation that effective and reliable driver-assistance systems exist that, if deployed, may over time provide significant benefits to Arizona and to other states for maintenance operations in severe winter storm conditions. These potential benefits include enhanced safety for snowplow operators and also for the public, as ADOT clears the highways with more efficient plowing operations.

Infrastructure-Based Systems: Years One to Four

Extensive evaluations were conducted of the two primary concepts for roadway-based vehicle guidance systems during four winters, from 1998 through 2002. The magnet-based Caltrans RoadView advanced snowplow was evaluated as it evolved over four winters, and ADOT also deployed the magnetic tape-based 3M Lane Awareness System for side-by-side testing during two of those seasons. Three previous ATRC reports describe those advanced-vehicle concepts, costs, and the Arizona evaluations in detail.

This project has validated the roadway-based vehicle guidance concepts developed by 3M and by the Caltrans program, but they are not the best solution for Arizona at their current cost levels. Overall, both systems proved their effectiveness and reliability, but it was also clear to ADOT that the cost of either system's infrastructure was prohibitive. Research was then redirected to commercial on-board warning systems in 2002-03, at a much more practical level of cost.

On-Board Systems: Year Five

The basic goal for the Org-based evaluation program was to determine whether either on-board system was effective and reliable in snowplowing operations. At the end of the winter, it was clear that neither collision warning radar nor infrared night vision, as tested, can solve all of the visibility problems for ADOT's snowplow crews.

The Bendix infrared night vision system worked effectively overall, but it had frequent snow buildup problems. The current model of this warning system did not fully meet ADOT's Year Five expectations in wet, wind-driven snow, or in rain.

The EVT-300 collision warning radar was effective, robust and reliable in all weather, day or night. The blind-spot warning and the SmartCruise were also key features. A critical factor in operator acceptance is the willingness to learn the system's strengths and weaknesses. Driver commitment is a greater factor for the CWS radar system than for the simpler infrared night vision concept.

Both systems were effective in some conditions, and both have design constraints and inherent technical limitations; they must primarily be considered as aids for an alert driver in impaired visibility, but not as a guidance system in whiteout storm conditions. Both systems should be evaluated further in the next winter season.

Project Implementation and Deployment

This research project has established the potential in ADOT fleet operations for on-board collision warning radar units and night vision cameras. These commercial on-board warning systems do not offer predictive guidance abilities to keep moving in very poor visibility, but they do improve the operator's awareness of the conditions and the potential obstacles in the road ahead. Further operational use of each system to gain additional field experience is expected to support further deployment decisions.

The near-term recommendation is to maintain the current deployment of the seven on-board warning systems for 2003-04 and into the future. This includes three XVision systems and four EVT-300 radar units. The ADOT-3M advanced snowplow is one of the radar units, and it will also continue operations indefinitely with the magnetic tape-based 3M Lane Awareness System.

The three XVision units will remain operational, with refinements (Figure 30), and will be evaluated further in the next winter. ADOT, ATRC, and Bendix have sought other approaches to improve XVision performance, and the lens cleaning problems may still be resolved. The EVT-300 deployment will continue in the next winter, and further installations of on-board collision warning radar systems are recommended.

Issues remain about full winter storm functionality, but both on-board warning systems are operationally effective and reliable at a cost that is minor with regard to equipping a new

snowplow vehicle. Any lingering concerns from Phase Three as to the winter maintenance applications of either system should be answered in the 2003-04 winter season.

The research project has achieved its goals and has expended its budget. This project report, the fourth, concludes the series. The ATRC will continue to assist with local testing as required, will act as a liaison with system vendors, and will solicit feedback from the local level. At the end of the 2003-04 winter, a follow-up survey will be distributed to those Orgs that are utilizing the two on-board warning systems. The ATRC will then prepare a summary memorandum for the TAC and its key project partners.

Program Vision

The vision of the ITS America organization was recently refined as follows: "A future where people and goods are transported without delay, injury, or fatality by integrated systems that are built and operated to be safe, cost effective, efficient and secure." Through five winters, the ADOT advanced snowplow research program has evaluated both infrastructure-based and on-board systems to meet such goals and to improve the operation of the state highway system.

This project's results indicate that on-board warning systems have the potential to improve snowplowing safety and efficiency on Arizona's highways. Now, the Department will have to make implementation decisions based on the research records, on a second full winter of operational deployment, and ultimately on the recommendations of rural district managers.

The transition from roadway-based to on-board systems may alter the deployment process for ADOT. The low cost of the two recommended aftermarket warning systems potentially allows the purchase decisions to be made at the district level, rather than centrally at the agency level.

On the other hand, an internal decision could be made to add these systems to the specifications for new snowplow trucks, but that process would make the deployment more gradual. This is an internal question for the agency, which the research project has not addressed.